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Colour Doppler Ultrasound in Diagnosing Venous Insufficiency A Comparison to Descending Phlebography

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Objective: *To evaluate the technique of ultrasound colour Doppler in diagnosing venous valvular incompetence in the lower leg.*
Design: *Prospective clinical study.*
Setting: *Department of clinical physiology.*
Materials: *44 patients (56 legs) referred with a clinical diagnosis of deep venous insufficiency.*
Chief outcome measures: *Colour Doppler and descending phlebography.*
Main results: *Using phlebography as a "gold standard" the accuracy of the colour Doppler technique varied between 93% and 55% for the different veins. For the superficial and deep femoral veins, the popliteal vein and the long and short saphenous veins the accuracy was between 90% and 70%. The lowest correlation was found for the deep calf veins (55–66% accuracy).*
Conclusions: *Colour Doppler was found to be a suitable technique for non-invasive investigation of patients with suspected venous insufficiency. Since the colour Doppler technique is non-invasive it is well suited for follow-up studies. Descending phlebography should be reserved as an adjunct technique in patients scheduled for valve reconstructive surgery.*

Introduction

Treatment of patients with chronic venous insufficiency is gaining greater attention in vascular surgical practice. The development of new therapeutic strategies, including various reconstructive procedures, has emphasized the need for better diagnostic techniques. Evaluation of valvular function is of particular interest in the workup of patients with chronic venous insufficiency.

Venous pressure recordings[1,2] and different plethysmographic techniques[3–5] have been used to evaluate overall valvular function in patients with incompetent veins. Using ultrasound techniques it is possible to investigate individual veins including visualisation of individual valves. With the exception of venous pressure measurements all these methods are non-invasive.

Continuous-wave Doppler ultrasound scanning has been used extensively in the diagnosis of venous insufficiency.[6–8] Since the examination has to be done blindly, without visualisation of the blood vessel studied, correct interpretation of the results depends largely on the experience of the investigator.

Duplex ultrasound has considerably improved the ability to localise blood flow information.[9–11] In this mode Doppler information from a local sample volume is combined with a real time image. The technique has shown good agreement with other methods such as venous pressure measurements[12] and descending phlebography[13] methods that are routinely used in diagnosing incompetent veins. It has also been used for reflux quantification in individual veins.[14,15]

In colour-coded Doppler, blood flow information from a number of sample volumes within a defined area of a real time image, is presented in colour. As with Duplex Doppler, colour Doppler can be used in the evaluation of incompetent venous valves. With this method an instant visualisation of blood flow is presented as well as the site of refluxes.[16–18]

Descending phlebography has been regarded as the "gold standard" in diagnosing venous insufficiency. However, phlebography is an invasive method, not free of complications, and Neglen and Raju[19] have

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observed that Duplex ultrasound scanning better reflects the clinical severity of the condition. Until the use of Doppler techniques, phlebography was the only alternative available for localising valvular refluxes.

The aim of the present study was to compare colour Doppler ultrasound and descending phlebography in the evaluation of venous valve function.

Material and Methods

Patients

All patients were referred from the surgical outpatient clinic during 1989-1992 with a clinical diagnosis of deep venous insufficiency (presence of distal leg oedema, pigmentation and/or active or healed ulcer) and were investigated for possible valvular surgery. Fifty-six legs of 44 patients, 22 men and 22 women, aged 17–76 years, were studied. Twenty-six patients had no previous history of deep venous thrombosis and were considered to have primary venous insufficiency, 17 had a previous history of deep venous thrombosis and were considered to have postphlebitic syndrome and one had a previously known valvular aplasia.

Healthy controls

To evaluate the colour Doppler method in normal veins 26 healthy volunteers (52 legs), eight men and 18 women, aged 16–50 years, were examined and used as a reference group. None of them had symptoms or history of venous disease. Phlebography was not performed in this group.

Phlebography

The technique described by Herman *et al.*[20] was used in the study with the patient in a semi-erect position

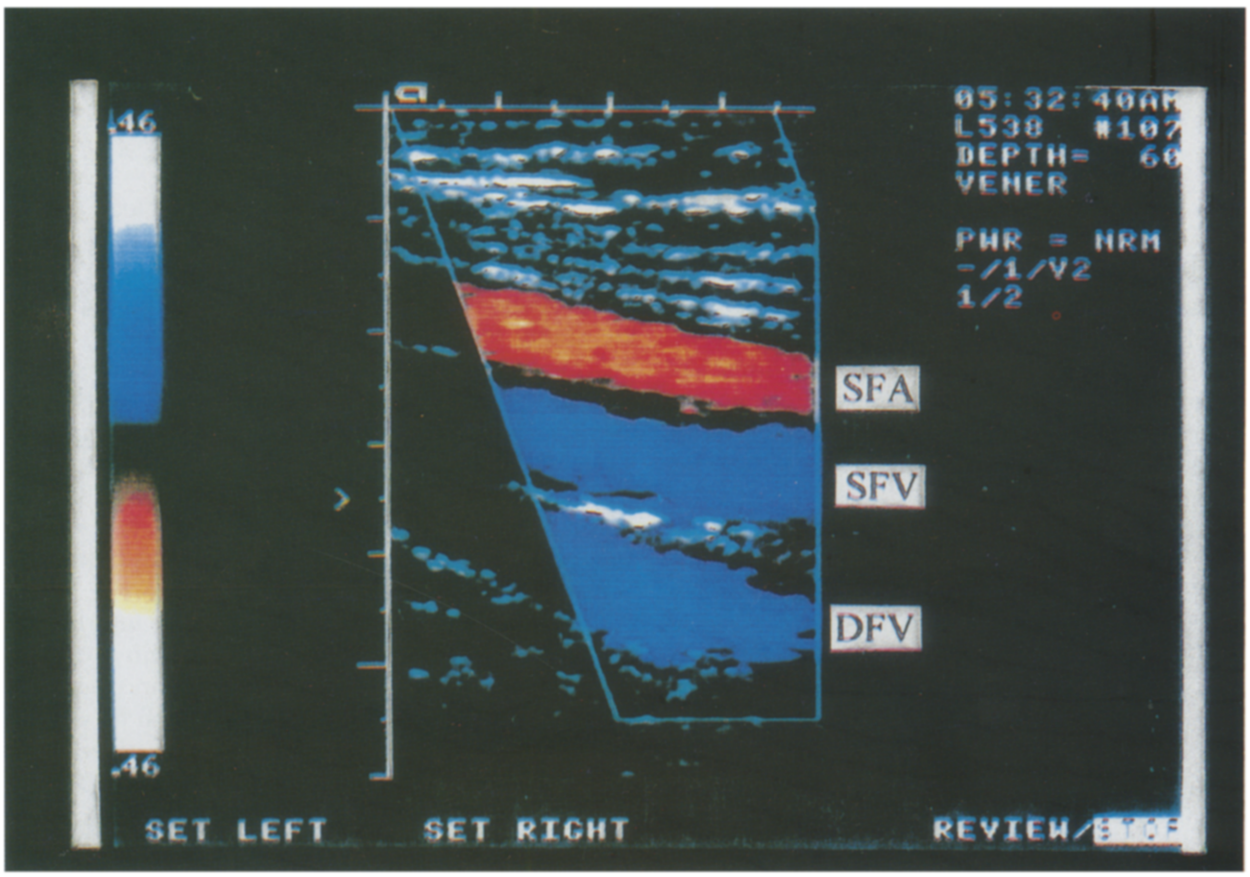

Fig. 1. Colour coded Doppler image with normal blood vessels. SFA, superficial femoral artery; SFV, superficial femoral vein; DFV deep femoral vein.

(60°) on a tilted radiographic table. A 6 F end-hole catheter was inserted into the common femoral vein. During fluoroscopy films were taken of the entire leg after repeated injections of 20 ml (total of 80 ml) contrast media (Iopromide, 240 mgI/ml, Ultravist, Schering Ag). Films were taken initially during normal breathing and then during a sustained Valsalva manoeuvre. The classification of reflux was based upon the extent of retrograde contrast leakage in each vein segment. Each vein scored either negative or positive for reflux. In order to reduce observer variation, the phlebograms were all read blindly by one experienced radiologist unaware of the colour Doppler scoring result.

Colour flow imaging

Colour flow examinations were performed using an Acuson 128 (Acuson Corp., Mountain View, CA, U.S.A.) computerized colour flow Duplex imager with a 5 MHz linear probe. All patients were examined by the same investigator.

In colour-coded Doppler blood flow is depicted in colour, e.g. red for flow in one direction (artery) and blue for flow in the opposite direction (vein). The higher the frequency shift and flow velocity the paler or more white is the colour. The colour flow map is superimposed on the real time anatomical gray scale image (Fig. 1).

Venous valvular incompetence was examined using the Valsalva test and manual calf compression. The increased abdominal pressure during the Valsalva manoeuvre provokes reversed (red colour) blood flow if the venous valves are incompetent (Fig. 2). Calf compression and decompression simulates the calf muscle pump. Valvular incompetence was shown by reversed (red colour) blood flow during decompression. A semi-quantitative grading (1 = mild, 2 = moderate and 3 = severe reflux) was based on blood flow velocity (frequency shift) estimated from the colour scale. Thus, high velocity and turbulence, as indicated by pale colour and sometimes a mosaic colour pattern,

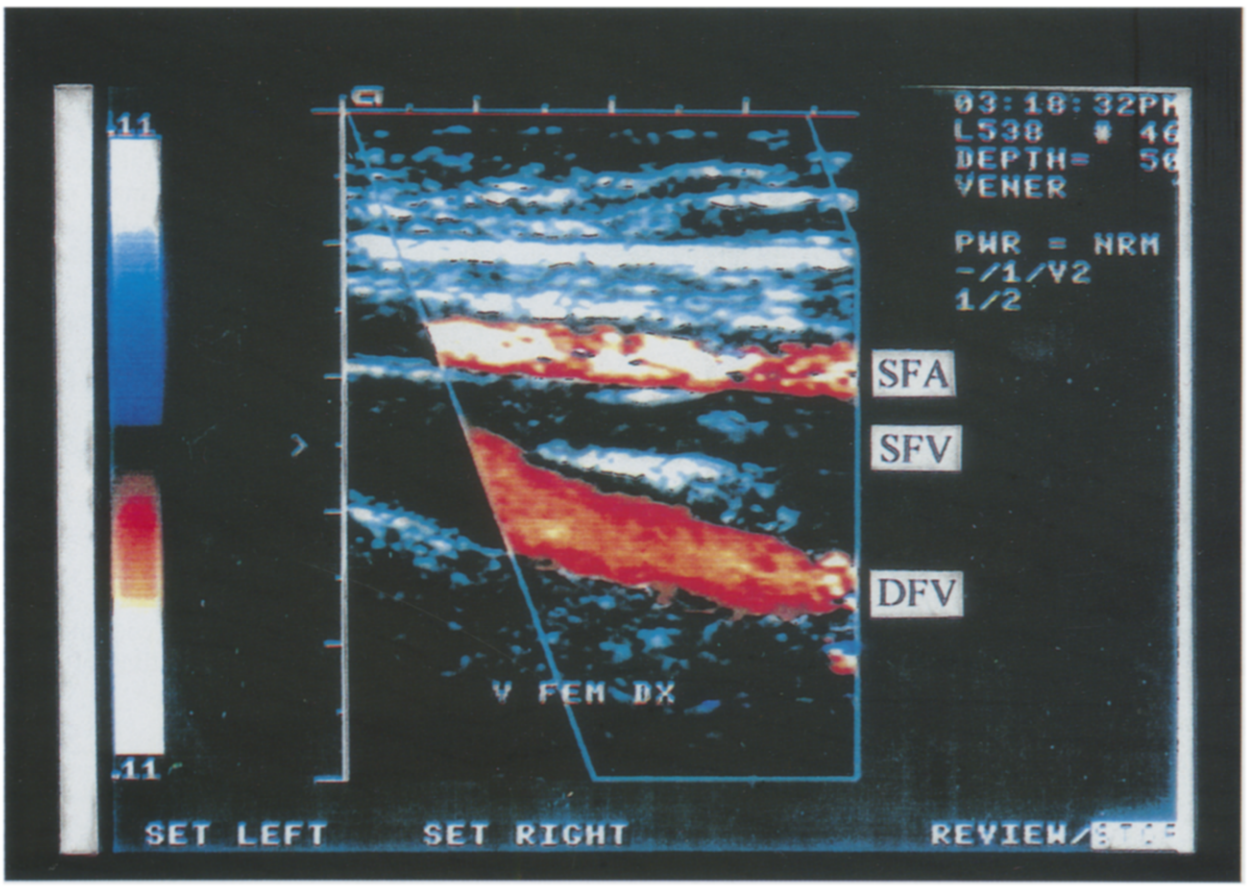

Fig. 2. Colour coded Doppler image with Valsalva-test demonstrating an incompetent deep femoral vein. SFA, superficial femoral artery; SFV, superficial femoral vein; DFV, deep femoral vein.

Table 1. Accuracy (%) of colour Doppler ultrasound compared to descending phlebography. Significant reflux with ultrasound, grades 1–3 (left) and 2–3 (right)

		Accuracy (%)	
	n	Grades 1–3	Grades 2–3
Superficial femoral vein	56	91	93
Deep femoral vein	56	77	64
Popliteal vein	56	75	70
Posterior tibial vein	38	55	55
Peroneal vein	38	66	66
Long saphenous vein	28	82	86
Short saphenous vein	44	68	70

gives high grading (grade 2-3). Low velocity, as indicated by darker colour, gives low grading (grade 1). Grade 1 corresponds to mean peak velocity < 10 (cm/s), grade 2 to mean peak velocity < 15 (cm/s) and grade 3 to mean peak velocity > 15 (cm/s). The same colour scale was used during the study. The vein diameter was not included in the grading.

The long saphenous and the femoral veins were examined with the patient in a supine position on a bed tilted 40°, feet down. After localising the saphenofemoral junction the patients were asked to perform the Valsalva manoeuvre. In the same way the confluence of the deep and the superficial femoral vein was localised and any reflux in the two veins studied. The superficial femoral vein was imaged down the thigh during repeated Valsalva manoeuvres.

The popliteal vein, short saphenous vein and sural veins were tested with the patient in prone position and tilted 40°, using both the Valsalva test and the calf compression test.

The posterior tibial and the peroneal veins were tested with the patient sitting on a bed with the foot in the examiner's lap. The calf veins were scanned with a medial transducer position. Only calf compression was used for testing reflux.

The colour flow examinations were performed at the Department of Clinical Physiology within 1–15 months of the phlebographic examinations, which were done at the Department of Radiology. The two studies were evaluated independently and blindly by two different investigators.

Results

The results are summarised in Table 1 which shows a comparison of colour Doppler ultrasound and descending phlebography with respect to the diagnosis of deep venous insufficiency. Cross-tabulation of the colour Doppler and the phlebographic data for individual veins is summarised in Table 2 (grades 1-3 were used as a significant reflux with colour Doppler). As can be seen from Table 2 all patients were examined for the superficial and deep femoral vein and the popliteal vein, while fewer patients were investigated for the calf veins and the superficial system due to incomplete initial examination of the calf veins and previous surgery of the superficial veins. The results from the Valsalva test were used when comparing the methods in all veins except the calf veins. We assigned a rating for clinical severity to each patient group (Fig. 3), (class 1 = swelling, 2 = pigmentation, 3 = active or healed ulcer) and found 63% of the postphlebitic patient group in class 3 and 21% in class 1. Within the primary patient group there were 14% in class 3 and 60% in class 1. Table 3 shows the distribution (%) of reflux with different gradings for each vein, examined with the colour Doppler. Reflux grades 2 and 3 were, in the majority of cases, seen in the superficial femoral and popliteal vein. When looking at the grading separately for each patient group (Fig. 4), 63% grade 3 were found in the popliteal vein in the postphlebitic group. In the primary group in the popliteal vein, 29% had grade 3. All the legs except two in the primary and one in the postphlebitic group had reflux both in the superficial femoral vein and in the popliteal vein according to colour Doppler. A negative result in the popliteal vein with positive reflux in the superficial femoral vein with descending phlebography was found in four in the primary group and one in the postphlebitic group.

Deep veins

The superficial femoral vein was studied with the two methods in 56 legs. Using a Doppler grading of ≥ 1 a

Table 2. Colour Doppler and descending phlebography data for individual veins

	Descending phlebography SFV (n = 56)		DFV (n = 56)		Popl (n = 56)		PTV (n = 38)		PER (n = 38)		LSV (n = 28)		SSV (n = 44)	
	+	–	+	–	+	–	+	–	+	–	+	–	+	–
Colour Doppler +	49	3	32	9	41	9	13	9	14	7	14	5	19	8
–	2	2	4	11	5	1	8	8	6	11	0	9	6	11

Abbreviations: SFV, superficial femoral vein; DFV, deep femoral vein; Popl, popliteal vein; PTV, posterior tibial vein; PER, peroneal vein; LSV, long saphenous vein; SSV, short saphenous vein.

Table 3. The distribution (%) of reflux grading 0–3 for each vein in 44 patients, examined with colour Doppler ultrasound.

Grading	0	1	2	3
SFV ($n = 56$)	7	2	30	61
DFV ($n = 56$)	27	20	41	13
Popl ($n = 56$)	11	13	38	39
PTV ($n = 38$)	42	11	34	13
PER ($n = 38$)	45	21	32	3
LSV ($n = 28$)	32	4	14	50
SSV ($n = 44$)	39	11	18	32

Abbreviations: SFV, superficial femoral vein; DFV, deep femoral vein; Popl, popliteal vein; PTV, posterior tibial vein; PER, peroneal vein; LSV, long saphenous vein; SSV, short saphenous vein.

significant reflux agreement was found in 51 of 56 legs (91%). If a grading of ≥2 was considered to be a significant reflux 52 out of 56 cases (93%) showed agreement.

The deep femoral vein was compared in 56 legs. With a significant reflux grade of ≥1 agreement was found in 43 of 56 legs (77%) and with a grade of ≥2 agreement was found in 36 of 56 legs (64%).

Similarily, agreement was found for the popliteal vein in 42/56 (75%) and 39/56 (70%) respectively.

In the calf the posterior tibial and peroneal veins were studied. Corresponding figures were 21/38 (55%) and 21/38 (55%) for the posterior tibial and 25/38 (66%) and 25/38 (66%) for the peroneal veins, respectively.

Superficial veins

With a significant reflux of grade ≥1 agreement was found in the long saphenous vein in 23 of 28 legs (82%) and with a grade of ≥2 agreement was found in 24 of 28 legs (86%). For the short saphenous vein the corresponding figures were 30/44 (68%) and 31/44 (70%), respectively.

Table 4. The distribution (%) of venous reflux grading 0–3 for each vein in 26 controls, examined with colour Doppler ultrasound.

Grading	0	1	2	3
SFV ($n = 52$)	60	25	15	0
DFV ($n = 52$)	85	8	8	0
Popl ($n = 52$)	87	6	8	0
PTV ($n = 52$)	98	0	2	0
PER ($n = 52$)	100	0	0	0
LSV ($n = 52$)	85	4	10	2
SSV ($n = 52$)	90	8	2	0

Abbreviations: SFV, superficial femoral vein; DFV, deep femoral vein; Popl, popliteal vein; PTV, posterior tibial vein; PER, peroneal vein; LSV, long saphenous vein; SSV, short saphenous vein.

Healthy controls

Table 4 shows the results from the different veins in the reference group. A reflux of grade ≤1 was seen in 0–40% in healthy symptomless individuals. In a few cases reflux grade 2 was observed. Reflux grade 3 was found in the long saphenous vein of one individual.

Discussion

A good agreement between the two methods was found for the superficial femoral vein and the long saphenous vein. For the deep femoral vein the agreement was less good if a reflux grade of ≥ 2 (with colour Doppler) was considered significant. If a grade of ≥1 (with colour Doppler) was used the agreement between the methods was acceptable for this vein also. The reason for the better agreement with a grade of ≥1 may be that the deep femoral vein is comparatively short with a low blood volume capacity. Consequently, the regurgitation flow will be relatively small and of short duration. In the deep femoral vein we found 9 of 11 (82%) grade 1 to be positive by descending phlebography.

There was an acceptable agreement between the two techniques for the popliteal vein and the short saphenous vein. Grade 1 in the popliteal vein was positive by descending phlebography in 5 of 7 cases (71%). The agreement was less good for the peroneal veins and poor for the posterior tibial veins. One reason for the limited agreement at the knee level or below may be that the Valsalva test, which was the only reflux provocation used with phlebography, is often inadequate for these veins due to the combination of local incompetence and competent proximal valves. Such a local incompetence may, however, be of great haemodynamic and clinical importance. The colour Doppler technique, combined with calf compression as used in the present study, is probably more accurate than phlebography for assessment of these veins. In this study two popliteal veins with local insufficiency by colour Doppler were negative by descending phlebography. Currently a standardised cuff-pressure in combination with the Valsalva test is used for all the veins except the calf veins, which still require manual compression.

Descending phlebography has been used as a "gold standard" for the diagnosis of insufficient venous valves but the technique has its limitations. In the present study five patients found to have normal phlebography had indisputable venous insufficiency in the long saphenous vein on colour Doppler. Some

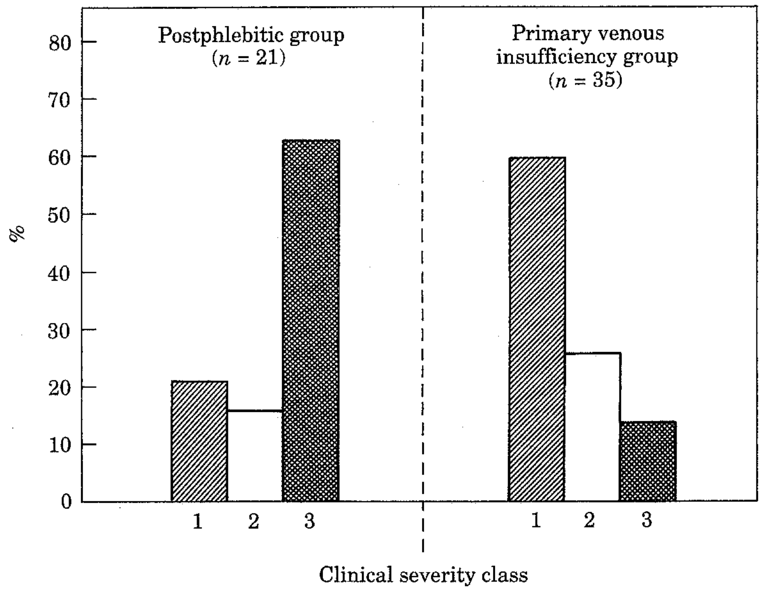

Fig. 3. Symptoms—clinical severity classes 1–3 (class 1, leg oedema; class 2, pigmentation; class 3, ulcer in postphlebitic and primary insufficiency in group). Number of legs (%) in each group.

of the discrepancies reported between the two methods studied could be explained by variation in the phlebographic method. Contrast injection distally to the saphenofemoral junction, competent proximal valves or proximal obstruction (post-thrombotic veins),[20] could give false-negative findings. The reflux could be influenced by the heavy contrast medium, thus causing reflux in normal valves.[21]

We found, as did Neglen and Raju,[19] that colour Doppler ultrasound reflected the clinical severity. The postphlebitic group was found to have 63% clinical severity class 3 (within the group) compared to 14% in the primary group. Colour Doppler reflux grade 3 was observed more frequently in the postphlebitic group—63% *vs.* 29% in the primary group. Colour Doppler is probably more sensitive in finding reflux in post-thrombotic veins than descending phlebography. Two postphlebitic patients with clinical severity class 3 and one patient with severity class 2 were negative with descending phlebography.

The control group demonstrated that slight degrees of reflux (grades 1 or 2) were seen frequently in healthy individuals with no symptoms of venous disease when examined with colour Doppler ultrasound. In fact, pronounced reflux was found in the long saphenous vein in one of 52 legs. This was in

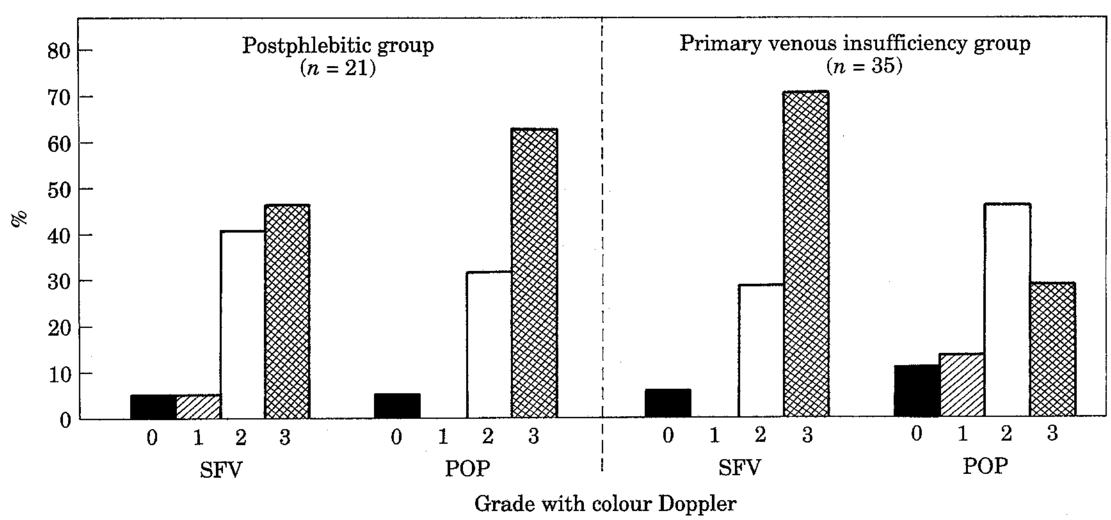

Fig. 4. Number of legs (%) in each group presenting venous insufficiency of varying grades. Grades 0–3 as determined by colour Doppler ultrasound. SFV, superficial femoral vein; POP, popliteal vein.

agreement with other studies where low grade reflux was observed with descending phlebography in normal legs.[21]

The agreement between colour Doppler (including Duplex Doppler) and descending phlebography in our study is equivalent to that of Duplex Doppler and phlebography observed by others.[13] This was not surprising since the two methods are based on the same Doppler information. Colour Doppler has an advantage over Duplex Doppler in being much faster and easier to use, e.g. when the entire leg is scanned.

Continuous-wave Doppler systems have been used widely in the diagnosis of venous insufficiency. These instruments are less expensive than Duplex or colour Doppler machines, but they are also more difficult to use and less precise, since the examination has to be done "blindly".

Venous pressure measurements and plethysmography are complementary methods in the workup of patients with deep venous insufficiency. They do not give the detailed anatomical information colour Doppler, Duplex Doppler or phlebography, but they do give a total figure of the venous incompetence, which is of great value.

It can thus be concluded that colour Duplex Doppler is a valuable non-invasive technique in the diagnosis of incompetent venous valves. It is well accepted by the patient and well suited for follow-up studies. The colour Doppler provides the surgeon with a better aid in planning venous surgery, including valve reconstruction surgery.

Before valve reconstruction surgery both methods should be used since they give complementary information. Colour Doppler can be recommended as a primary non-invasive measurement but phlebography should be used for preoperative mapping, since this method enables better visualisation of the position of the valves.

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